

REMARKS

Applicant hereby submits amendments to correct the Examiner's objection to the specification and the abstract.

Claims 1-30 were rejected in the present patent application. Applicant has amended claims 1, 2, 8, 9, and 11 and cancelled claims 5, 10, and 16-30. Applicant respectfully requests reconsideration of pending claims 1-4, 6-9, and 11-15 in the present patent application in view of the amendments and remarks.

Rejection under 35 USC 112, second paragraph

Claims 1-30 were rejected under 35 USC 112, second paragraph. In response, Applicant has amended the claims and presents the amended claims to overcome the Examiner's rejection.

Rejection under 35 USC 102(b)

Claims 1-15 and 16-19 were rejected under 35 USC 102(b) as being anticipated by Bestwick et al. Claims 5, 10 and 16-19 have been cancelled. However, Applicant respectfully disagrees with the rejection of claims 1-4, 6-9, and 11-15 under 102(b). Applicant submits that the Bestwick does not anticipate claim 1 because Bestwick fails to teach, describe, or suggest the limitations:

“soldering a semiconductor optical gain chip to a micromachined silicon bench to create an internal element of said laser; and

coupling said optical gain chip to a silicon-dioxide and silicon-oxynitride based waveguide terminating in an external feedback element, said step of coupling further comprises:

using a flip-chip aligner-bonder to horizontally align the coupling of said gain chip to said waveguide; and

using a plurality of micromachined stand-offs to vertically align the coupling of said gain chip to said waveguide.”

The claims of present invention comprise an important aspect of making narrow linewidth hybrid laser -- the alignment of the gain chip to the waveguide with the Bragg grating. Bestwick does not specify how this can be achieved. There is no mention in Bestwick of either the horizontal or the vertical alignment limitation of the present invention. Thus Bestwick does not anticipate claim 1. As claim 2-4, 6-9 and 11-15 all depend on claim 1, their rejection based on 35 USC 102 is overcome as well.

Rejection under 35 USC 103(a)

Claims 20-23, 27-30

The Examiner has rejected claims 20-23, 27-30 under 35 USC 103 as being unpatentable over Bestwick in view of Deacon. These claims have been cancelled. However, claims 1-4, 6-9, and 11-15 correspond to the subject matter in these cancelled claims. Applicant respectfully disagrees with the basis that Examiner used in rejecting these claims. The Examiner has cited that Deacon discloses the use of a flip-chip bonder-aligner. Although Deacon specifies the use of flip-chip bonder which facilitates horizontal alignment of the gain chip to the waveguide, the patent is vague as to how the

vertical alignment is achieved. This step, however, is crucial since the vertical tolerance is the tightest in the fabrication process. Deacon's approach is to control the thickness of the bonding layer (Fig. 1, col. 6, lines 45-50 and Fig. 3, col. 17, lines 13-36). This works poorly in practice since the bonding layer must be soft and pliable. The thickness of such a layer is subject to change when the gain chip is pressed upon it, thus defeating the intent to control layer thickness. In contrast, the approach of the present invention is to create and use hard micromachined stand-offs that support the gain chip. Since they need not to be soft, such stand-offs are not subject to change in thickness during the bonding process. In the present invention, the soft solder used to attach the gain chip to the substrate may be squashed during the bonding process so the vertical alignment is solely determined by the hard stand-offs. The present invention thus offers more precise control in the process of vertically aligning the gain chip. Therefore, Applicant submits that neither Bestwick nor Deacon discloses the limitations of the present invention and the rejection under 35 USC 103(a) has been overcome.

CONCLUSION

The Examiner has rejected claims 1-30 and made objections to various parts of the specification and abstract. Applicant has corrected the defects in the specification and abstract, cancelled claims 5, 10, and 16-30 and amended claims 1, 2, 8, 9, 11. Applicant submits that pending claims 1-4, 6-9, and 11-15 are now in a condition for allowance.

Respectfully submitted,

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MARKED UP VERSION SHOWING CHANGES TO SPECIFICATION

The paragraph beginning at page 7, line 3 has been amended as follows:

The present invention is a method and apparatus for creating a narrow linewidth hybrid semiconductor laser. According to one embodiment of the present invention, [silicon-oxide] silicon-dioxide and silicone-oxynitride based external feedback elements are used to create the laser. According to another embodiment of the present invention, these feedback elements use Bragg gratings with a resonate optical reflector, which is formed by the coupling, and the periodic variation of the refractive index of two Bragg gratings to a main waveguide trunk (path of the laser beam). According to another embodiment of the present invention, the laser is precisely attached to the waveguide by the use of a flip-chip aligner-bonder.

The paragraph beginning at page 7, line 13 has been amended as follows:

According to one or more embodiments of the present invention, the laser has a narrow linewidth range (tens of kHz range) making it accurately tunable to facilitate locking to an ultra-stable cavity. The hybridization technology achieves narrow linewidth in miniature micromachined units. A semiconductor optical gain chip is soldered to a micromachined silicon bench, and the semiconductor optical gain chip is coupled into a [silicon-oxide] silicon-dioxide/silicon-oxinitride/silicon-dioxide ($\text{SiO}_2/\text{SiON}/\text{SiO}_2$) waveguide terminating in an appropriate feedback element, for example, a Bragg grating that facilitates linewidth reduction.

The paragraph beginning at page 10, line 10 has been amended as follows:

The present invention utilizes [silicon-oxide] silicon-dioxide and silicon-oxynitride ($\text{SiO}_2 - \text{SiON}$) based passive external feedback elements that are coupled with the active internal elements to create the narrow linewidth hybrid laser. According to one embodiment of the present invention, these external feedback elements are made to closely match the modes of a standard gain chip. At the same time, using the hybridization technique explained below, the present system enables the fabrication of rugged, reliable lasers for large range and space expanses, for example, deep sea or outer space exploration, and communications. Since these external feedback elements do not need gain chips with mode converters that are expensive and not readily available, the present invention cuts on cost and the time to make a rugged, narrow linewidth laser.

The paragraph beginning at page 16, line 20 has been amended as follows:

According to another embodiment of the present invention, the semiconductor optical gain chip is coupled into a [silicon-oxide] silicon-dioxide/silicon-oxynitride/silicon-dioxide ($\text{SiO}_2/\text{SiON}/\text{SiO}_2$) waveguide terminating in an appropriate feedback element, for example, a Bragg grating that facilitates linewidth reduction. The light guides may be deposited using a technique called the Plasma Enhanced Chemical Vapor Deposition. The waveguide layout using this technique is illustrated in Figure 5. The top cladding layer 500 and the lower cladding layer 520 are made of [silicon-oxide] silicon-dioxide, while the core layer 510 is made of silicon-oxynitride. The waveguide mode 530 is placed in the center of the core layer. The $\text{SiO}_2/\text{SiON}/\text{SiO}_2$ waveguide is placed on top of substrate 540.

The paragraph beginning at page 23, line 3 has been amended as follows:

The present invention is a method and apparatus for creating a narrow linewidth hybrid semiconductor laser using [silicon-oxide] silicon-dioxide and silicone-oxynitride based external feedback elements. These feedback elements use Bragg gratings formed by periodic variation of the refractive index with a resonate optical reflector. The laser has a narrow linewidth (in the tens of kHz range), which can be accurately tunable to facilitate locking to an ultra-stable cavity. A semiconductor optical gain chip is soldered to a micromachined silicon bench. This semiconductor optical gain chip is coupled into a silicon-dioxide/silicon-oxinitride/silicon-dioxide (SiO₂/SiON/SiO₂) waveguide terminating in an appropriate feedback element that facilitates linewidth reduction. In order to suppress the loss and scattering at the SiO₂/SiON/SiO₂ interface and due to residual facet reflectance, an antireflection coating is applied. In order to achieve low loss due to mode mismatch, the waveguide modes are tailored to match the gain chip modes.

MARKED UP COPY OF CLAIMS

Per 37 CFR 1.121(c)(1)(ii)

1. (AMENDED) A method for creating a narrow linewidth hybrid semiconductor laser comprising:

[using coupling silicon-oxide and silicon-oxynitride based external feedback elements;

attaching said narrow linewidth hybrid semiconductor laser to a waveguide; and

soldering a semiconductor optical gain chip that acts as the internal element to a micromachined silicon bench.]

soldering a semiconductor optical gain chip to a micromachined silicon bench to create an internal element of said laser; and

coupling said optical gain chip to a silicon-dioxide and silicon-oxynitride based waveguide terminating in an external feedback element, said step of coupling further comprises:

using a flip-chip aligner-bonder to horizontally align the coupling of said gain chip to said waveguide; and

using a plurality of micromachined stand-offs to vertically align the coupling of said gain chip to said waveguide.

2. (AMENDED) The method of claim 1 wherein said external feedback element[s] [use] comprises Bragg gratings.

8. (AMENDED) The method of claim 1 wherein [the hybridization method used to create] said step of coupling [said narrow linewidth hybrid semiconductor laser] is achieved in miniature micromachined units.

9. (AMENDED) The method of claim 1 wherein said [semiconductor optical gain chip is coupled into a silicon-oxide/silicon-oxinitride/silicon-oxide] waveguide further comprises:

a first layer of silicon-dioxide;

a layer of silicon-oxinitride; and

a second layer of silicon-dioxide.

11. (AMENDED) The method of claim 9 wherein [said silicon-oxide/silicon-oxinitride/silicon-oxide interface is] the interface between said first layer and said silicon-oxinitride layer and the interface between said second layer and said silicon-oxinitride layer are coated with an antireflection coating in order to further reduce loss and scattering at said interface[s].



CLEAN SET OF CLAIMS

1. A method for creating a narrow linewidth hybrid semiconductor laser comprising:

soldering a semiconductor optical gain chip to a micromachined silicon bench to create an internal element of said laser; and

coupling said optical gain chip to a silicon-dioxide and silicon-oxynitride based waveguide terminating in an external feedback element, said step of coupling further comprises:

using a flip-chip aligner-bonder to horizontally align the coupling of said gain chip to said waveguide; and

using a plurality of micromachined stand-offs to vertically align the coupling of said gain chip to said waveguide.
2. The method of claim 1 wherein said external feedback element comprises Bragg gratings.
3. The method of claim 2 wherein said Bragg gratings are formed by the coupling of a first Bragg grating and a second Bragg grating to a main waveguide trunk.
4. The method of claim 3 wherein said first Bragg grating and said second Bragg grating are formed by the periodic variation of the refractive index of said first Bragg grating and said second Bragg grating.

6. The method of claim 1 wherein said narrow linewidth is in the tens of kHz range.

7. The method of claim 1 wherein said narrow linewidth hybrid semiconductor laser is tunable to facilitate locking to a cavity.

8. The method of claim 1 wherein said step of coupling is achieved in miniature micromachined units.

9. The method of claim 1 wherein said waveguide further comprises:
a first layer of silicon-dioxide;
a layer of silicon-oxinitride; and
a second layer of silicon-dioxide.

11. The method of claim 9 wherein the interface between said first layer and said silicon-oxinitride layer and the interface between said second layer and said silicon-oxinitride layer are coated with an antireflection coating in order to further reduce loss and scattering at said interface.

12. The method of claim 3 wherein said waveguide is tailored to match said gain chip in order to further reduce loss due to mismatch of modes of said waveguide and said gain chip.

13. The method of claim 12 wherein said waveguide and said gain chip are precisely aligned to each other in order to further reduce loss due to mismatch of modes of said waveguide and said gain chip.

14. The method of claim 13 wherein said precise alignment in the vertical direction is achieved through the use of micromachined stand-offs.

15. The method of claim 13 wherein said precise alignment in the horizontal direction is achieved during the soldering operation through the use of said flip-chip aligner-bonder.